STRANDED SHINGLE BEACH RIDGES, UPPER SPENCER GULF, SOUTH AUSTRALIA: EVIDENCE FOR HIGH WAVE ENERGY DISSIPATION DURING THE LATE PLEISTOCENE

by J. R. HAILS* and V. A. GOSTIN†

Summary

HAILS, J. R. & GOSTIN, V. A. (1978) Stranded shingle beach ridges, upper Spencer Gulf, South Australia: evidence for high wave energy dissipation during the late Pleistocene. *Trans. R. Soc. S. Aust.* **102**(6), 169-173, 31 August, 1978.

Stranded shingle beach deposits have been traced over a distance of some 50 km from near the head of Spencer Gulf southwards along its western shore to Stony Point, near Whyalla. These deposits, which consist of moderately sorted, rounded to sub-angular pebbles and cobbles, form well preserved ridges 3-5 m above present mean sea level. Entire, non-abraded shells of the estuarine bivalve *Anadara trapezia* (Deshayes 1840) are abundant in the beach deposits and, because this species is now extinct in South Australia, a Pleistocene age is indicated for the ridges.

The movement of gravel by present-day waves in the northern part of Spencer Gulf is restricted compared with that indicated by the stranded, shingle beach ridges. During the Pleistocene it appears that the combination of a high sea level, large fetch, strong easterly winds and high wave energy dissipation along the shoreline emplaced the relict shingle beach deposits.

Introduction

Evidence for high stands of sea level during both the Pleistocene and Holocene epochs has been cited from several regions of Australia (Hails 1965; Thom *et al.* 1969; Gill & Amin 1975; Thom & Chappell 1975; Cook *et al.* 1977). Some of this evidence pertains to shore platforms which may have been abraded several times during eustatic changes of sea level in the past. The rate at which shore platforms are modified by marine abrasion varies widely because of differential weathering and erosion controlled by rock composition, texture and structure and, therefore, it is difficult to relate them to former still stands of sea level. Furthermore, such a correlation is almost impossible anyway, because modern sea level around Australia is believed to be within a metre or so of its former level during the late Pleistocene (Hails 1968; Chappell 1976).

The problem of dating Pleistocene sea levels in coral reef areas has been outlined by Chappell *et al.* (1974). In addition, many C^{14} dates reported from Pleistocene strandlines near present sea level have proved to be unreliable, and therefore other dating methods must be used before an accurate reconstruction of past events can be undertaken (Thom 1973). Because of these facts, it is now generally recognised by researchers conducting process studies in the coastal zone that depositional features, such as barrier beaches containing diagnostic fossils, datable organic material and soil horizons, are better indicators of relative changes in mean sea level.

During a recent survey of the coast of upper Spencer Gulf, as part of a detailed study of the submarine geology and nearshore processes within the region, the writers traced well preserved stranded shingle beach deposits from Black Point, 15 km northeast of Whyalla, northwards along the shoreline to a point opposite Snapper Point 8 km south of Port Augusta, a distance of about 50 km (Fig. 1). The term 'shingle' is used here to describe beach gravels composed predominantly of pebbles and cobbles.

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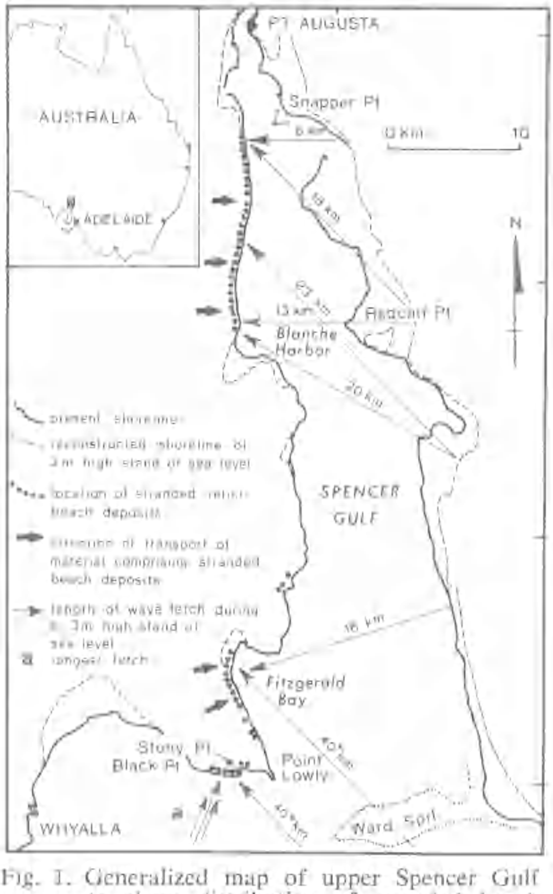

Fig. 1. Generalized map of upper Spencer Gulf to show distribution of stranded beach deposits and maximum fetches during a +3 m-high stand of Pleistocene sea level.

The purpose of this paper is to describe briefly the main diagnostic features of these deposits and to consider the conditions under which they may have been emplaced during a Pleistocene high stand of sea level. As far as the writers are aware, these deposits have only been recorded on the Cultana (1:63360) geological map, and in the Black Point—Point Lowly area by Crawford (1963) who described them as Quaternary 'emerged offshore bars' tectonically elevated to their present position. However, Firman (1965), without citing Crawford's earlier work, mentions a 10-ft Tertiary-Quaternary high stand of sea level and associated gravel beach ridges.

Stranded beach deposits

Most of the stranded beach deposits form sinuous, flat-topped ridges which stand 3-5 m above mean sea level (Fig. 2A). They are usually narrow, no more than 10-15 m wide, although at one locality, 15 km south of Port Augusta, one ridge is more than 75 m in width (Figs 2E and 2F). The seaward slope of these ridges usually exceeds 30°, which is generally steeper than the landward or lee slope. The 75 m-wide ridge shown in Figs 2E and 2F has an extremely gentle lee slope and resembles a washover fan, a feature deposited on a coast during hurricanes and cyclones when beach ridges are extensively eroded by storm waves. In some localities the shingle deposits form cliffs behind the modern beach. An intervening narrow 'flat' between the cliffs and the backshore is now used as a road for vehicular traffic, particularly between Port Augusta and Blanche Harbour. Many ridges are vegetated with low scrub, but this is generally absent from the flat, crestal surfaces because of the extreme permeability of the gravels.

Rounded to sub-angular pebbles and cobbles of Precambrian sandstones and quartzites are the main constituents of the ridges (Fig. 2B). These have been derived from either alluvial fans, dissected by ephemeral streams, or colluvium that mantles neighbouring cliffs usually cut in bedrock. A few of the cliffs, though, comprise remnant alluvial-fan deposits. In the Point Lowly area the shingle comprising the ridges is significantly more rounded than that on most other beaches where the material has been derived directly from cliffs and outcrops of Precambrian bedrock.

At most localities the stranded shingle is moderately sorted and varies in size from large flat cobbles, as in the Black Point-Point Lowly sector, to more ubiquitous sub-rounded, small cobbles and pebbles elsewhere along the Gulf coast. Some lateral reduction in mean clast size has been noted away from source areas, but the alongshore movement of gravel has been minimal, as evidenced by the absence of recurved spits.

The thick-shelled estuarine cockle *Anadara trapezia* is abundant in the relict beach deposits especially in Fitzgerald Bay and the northernmost part of the Gulf (Figs 2C and 2D). According to Gill (1977), this species migrated to Australia during the Pleistocene epoch, probably more than 400,000 years ago, and became abundant in southern Australia during the Last Interglacial. However, *A. trapezia* is absent from the modern sediments of South Australia except where it has been reworked from Pleistocene deposits. The shells found in the stranded shingle ridges are entire, nonabraded valves and therefore do not appear to have been reworked from early Pleistocene deposits.

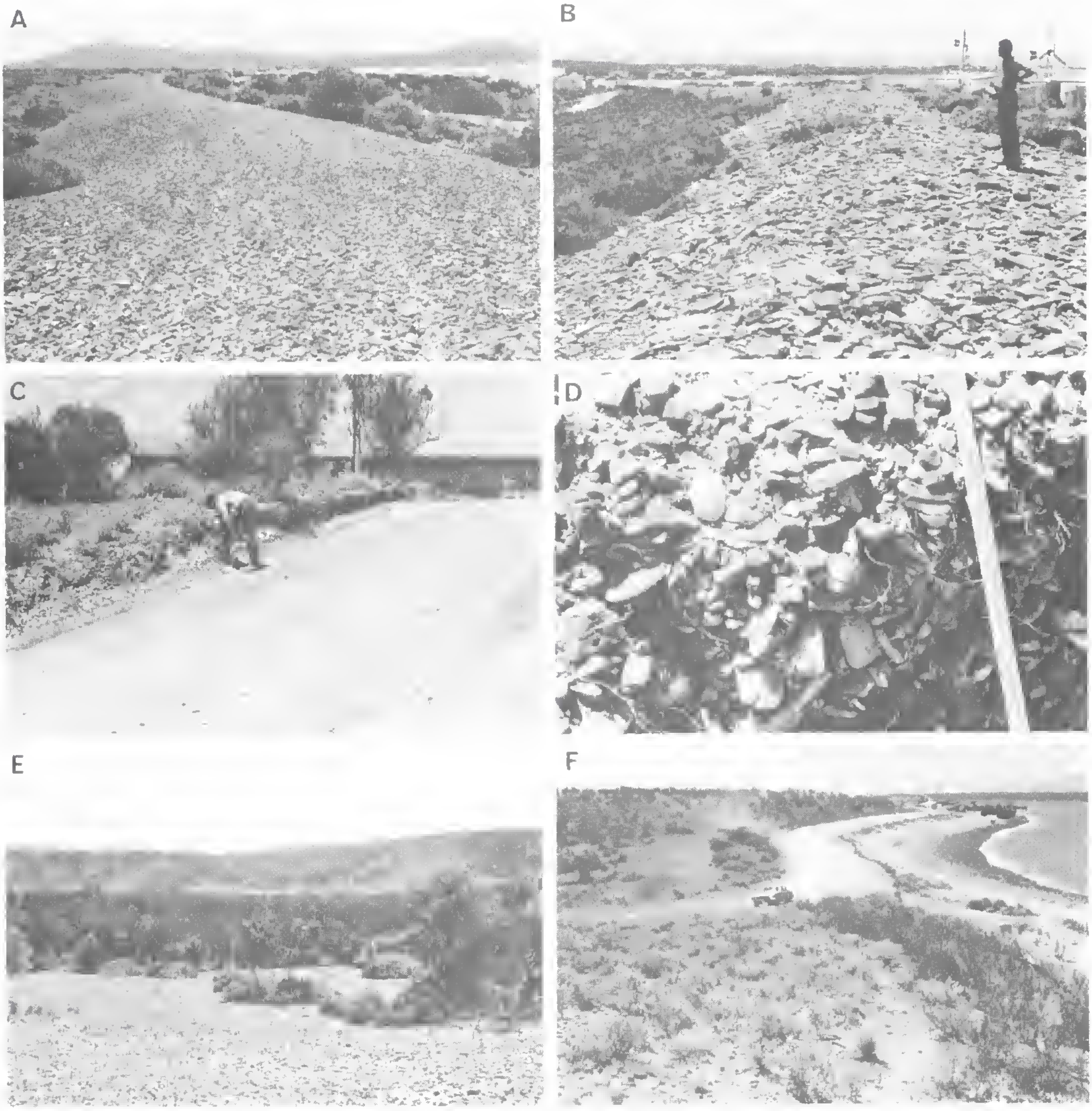

Fig. 2A Stranded sinuous shingle beach ridge, looking north, Fitzgerald Bay. (Map Ref. 568534, Cultana 6432-III, 1:50 000).
Fig. 2B. Cobbles and scattered boulders comprising 3m beach ridge, Stony Point. View looking east towards Point Lowly. (Map Ref. 575456, Mambray 6432-II, 1:50 000).
Fig. 2C. Road cut through stranded shingle beach, containing abundant shells of *Anadara trapezia*, Saints Bay. (Map Ref. 580825, Davenport 6432-I, 1:50 000).
Fig. 2D. Part of road-cut in Fig. 2C showing *in situ Anadara trapezia*.
Fig. 2E. Landward margin of non-vegetated part of washover fan shown in Fig. 2F, and located 15 km south of Port Augusta. (Map Ref. 586865, Davenport 6432-I, 1:50 000).
Fig. 2F. View looking north showing washover fan with road on seaward side. Location as in Fig. 2E.

Discussion

No marine gravels have been located above the Pleistocene shoreline reported here, and very little gravel has been recovered in 3-5 m long, undisturbed vibrocores obtained from the seabed immediately offshore from the stranded shingle beach ridges. Therefore, it may be inferred that there has never been a substantial offshore reservoir of shingle in upper Spencer Gulf. Also, the fact that the shingle ridges display minimal grading, and no marked variation in width in an alongshore direction, suggests that there has been only minor northerly or southerly movement of beach material along

the embayed western shore of the Gulf in the past. The shingle has been derived from either outcrops of Precambrian quartzite or, more commonly, adjacent dissected alluvial fans which, as stated previously, form cliffs in some localities. It appears that the shingle was moved a short distance offshore, abraded in the near-shore zone and ultimately deposited as beach ridge material. In the relatively confined and sheltered parts of northern Spencer Gulf today, the movement of beach gravel is somewhat restricted within the inter-tidal zone by the mangrove *Avicennia marina* var. *resinifera* ((Forst. f.) Bakh v.d. Brink 1921) which grows on sub-angular sandy gravel and often between blocks of cemented Pleistocene conglomerate.

If Gill's thesis on the migration of *Anadara trapezia* is correct the stranded beach ridges which contain *A. trapezia* could have been built during either the Last Interglacial (120,000 years BP) or during a late Pleistocene interstadial, about 30,000 years BP because, as stated above, there is no evidence of an earlier Pleistocene sea level in upper Spencer Gulf. The presence of entire and unweathered shells, the well-preserved beach ridge surfaces, and the lack of fine windblown sediment on the ridge tops collectively suggest a very late Pleistocene age, but dating is obviously needed to establish an absolute age.

Regardless of the age of the stranded beach ridges, their presence is significant in determining past wave and wind regimes in the northern part of the Gulf. In this context, it is pertinent to consider the factors involved in the formation of such ridges. In the area of generation, the height of sea waves and their period are functions of the duration that the wind (storm) blows (D), the wind velocity (U), and the length of fetch (F) or the distance over which the wind blows. The fetch length is a major factor because it determines not only the time during which wind energy is transferred to the sea surface, but also the wave height (H) and period (T). Thus, for relatively short fetches, waves depend upon the fetch length (F) and wind velocity (U), and for long fetches on wind velocity and duration (D). This relationship can be written symbolically as $H,T = f(U,F,D)$.

It can be seen in Figure 1 that winds would have been mainly southeasterly in order to build most of the shingle ridges because smaller waves are generated from other directions. Even if easterly winds occurred less frequently than all others they were, nevertheless, the dominant winds that generated waves able to move shingle and form beach ridges. Fine sand and mud could have been moved selectively by currents and carried alongshore in suspension. It is also known that variation in wave energy is partly responsible for variations in particle size parallel to the shoreline and that larger particles are associated with greater energy. Theoretically, wave heights of about 3-5 m above mean sea level can be generated by winds of 50 knots blowing over a fetch of 90 km—one which far exceeds those in upper Spencer Gulf today—but waves of this height are usually destructive.

On the other hand, shingle can be deposited a few metres above a given datum by constructive swell and, in the light of this fact, it should be considered whether or not the stranded ridges were emplaced during a +3 m, or slightly lower, stillstand of the sea during the Pleistocene. Certainly, the 2 m difference in the maximum height of ridge crests reported here could reflect degree of exposure to, and variations in, wave enegy as determined by the length of fetch in the past, and coastal configuration.

The present tidal range in the Gulf is about 2 m, but Radok & Raupach (1977) have shown in recent studies that weather systems raise mean sea level against the south coast of Australia because of barometric pressure and wind stress operating over large areas of the Southern Ocean. Waves and tides, in turn, are superimposed on this mean sea level. Because changes in mean sea level are relatively slow, they are able to penetrate into confined water bodies like Spencer Gulf and Gulf St Vincent in South Australia, and may consequently induce notable water exchange and sediment movement. Coastal erosion along the southern margin of Australia today can, in fact, be linked to these variations. If similar meteorological conditions existed in the late Pleistocene, and isobaric pressure gradients were steeper, there is little doubt that shingle ridges could also have been constructed as a result of higher wave energy in upper Spencer Gulf.

It is worth mentioning that studies by Veeh (1966) in the Central Pacific have shown that sea level stood approximately 2-6 m above modern datum during the Last Interglacial. However, wide-scale correlations can be suspect because of regional and local factors, some of which have been discussed here with regard to South Australia.

As only a small area of the Gulf is under review in this paper the writers cannot debate with justification whether the ridges have been elevated as a result of tectonic activity as proposed for the Black Point-Lowly Point area by Crawford (1963). Although tectonism cannot be ignored on a much larger regional scale it seems unlikely, for the reasons just cited, that it can exclusively account for the 3-5 m beach ridges.

In conclusion available evidence indicates that the stranded shingle ridges in upper Spencer Gulf are Pleistocene in age, and were most likely built during a +3 m high stand of sea level when easterly winds predominated in the region and large waves from the southeast dissipated their edges along the western shore. No corresponding shingle ridges are known along the eastern counterpart of the Gulf despite the fact that southwesterly waves travel across the longest fetch today.

Acknowledgement

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References

CHAPPELL, J. (1976) Aspects of late Quarternary palaeogeography of the Australian-East Indonesian Region. *In* Kirk, R. L. & Thorne, A. G. (eds.), "The Origin of the Australians". 11-22 (Human Biology Series No. 6, Australian Institute of Aboriginal Studies, Canberra; Humanities Press, New Jersey).

CHAPPELL, J., BROECKER, W. S., POLACH, H. A. & THOM, B. G. (1974) Problem of dating Upper Pleistocene sea levels from coral reef areas. *In* "Proceedings of the Second International Coral Reef Symposium" 2. 563-571 (Great Barrier Reef Committee, Brisbane, December 1974).

COOK, P. J., COLWELL, J. B., FIRMAN, J. B., LINDSAY, J. M., SCHWEBEL, D. A. & VON DER BORCH, C. C. (1977) The Late Cainozoic sequence of southeast South Australia and Pleistocene sea-level changes. *Bur. Min. Res. J. Geol Geophys.* **2**, 81-88.

CRAWFORD, A. R. (1963) Quaternary sedimentary breccias and emerged offshore bars near Point Lowly. *Quart. geol. Notes, geol. Surv. S. Aust.* **5**, 1-2.

FIRMAN, J. B. (1965) Late Cainozoic sedimentation in northern Spencer Gulf, South Australia. *Trans. R. Soc. S. Aust.* **89**, 125-131.

GILL, E. D. (1977) Time of migration of the mollusc *Anadara* to SE Australia. *Search* **8** (1-2), 40-41.

GILL, E. D. & AMIN, B. S. (1975) Interpretation of 7.5 and 4 meter Last Interglacial shore platforms in southeast Australia. *Ibid.* **6**(9), 394-396.

HAILS, J. R. (1965) A critical review of sea level changes in Eastern Australia since the Last Glacial. *Aust. Geogr. Stud.* **3**, 63-78.

HAILS, J. R. (1968) The Late Quaternary history of part of the Mid-North Coast New South Wales, Australia. *Trans. Inst. Brit. Geogr.* **44**, 1059-1069.

RADOK, R. & RAUPACH, M. (1977) Sea level and transport phenomena in St. Vincent Gulf. *Inst. Engrs 3rd Aust. Conf. Coastal Ocean Eng.* 103-109.

THOM, B. G., HAILS, J. R., & MARTIN, A. R. H. (1969) Radiocarbon evidence against higher Postglacial sea levels in eastern Australia. *Marine Geol.* **7**(2), 161-168.

THOM, B. G. (1973) The dilema of high interstadial sea levels during the last glaciation. *Progr. Geogr.* **5**, 170-245.

THOM, B. G. & CHAPPELL, J. (1975) Holocene sea levels relative to Australia. *Search* **6**(3), 90-93.

VEEH, H. H. (1966) Th^{230}/U^{238} and U^{234}/U^{238} Ages of Pleistocene high sea level stand. *J. Geophys. Res.* **71**, 3379-3386.

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